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(71) Applicant *(for all designated States except US)*: ASEA BROWN BOVERI AB [SE/SE]; S-721 83 Västerås (SE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: LEIJON, Mats [SE/SE]; Hyvlargatan 5, S-723 35 Västerås (SE). HÖRNFELDT, Sven [SE/SE]; Götgatan 4 A, S-724 62 Västerås (SE). KYLANDER, Gunnar [SE/SE]; Stentorpsgatan 16 A, S-723 43 Västerås (SE). HOLMSTRÖM, Göran [SE/SE]; Tistelvägen 22 G, S-191 63 Sollentuna (SE).

(74) Agent: EMTEDAL, Artur; L.A. Groth & Co. KB, P.O. Box 6107, S-102 32 Stockholm (SE).

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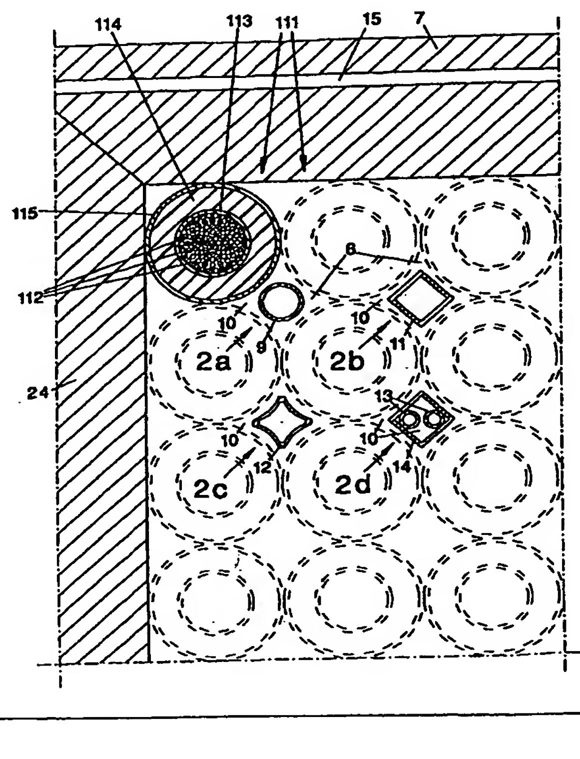
(57) Abstract

Gas or water-cooled transformer/reactor and a method for manufacturing the same having at least one gas or water-cooled transformer/reactor provided with winding, the winding comprising a high-voltage cable (111) and at least one additional member (9, 11, 12, 13, 14, 50, 55, 60, 65, 70, 75) is wound into the winding (2, 3, 4) arranged around the legs (22, 23, 24) of the transformer/reactor.



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METHOD AND DEVICE IN MANUFACTURING A TRANSFORMER/ REACTOR

TECHNICAL FIELD:

The present invention relates to a gas or preferably water-cooled, cable-wound power transformer and to a process for manufacturing such a cable-wound power transformer in the voltage range up to 400 kV.

BACKGROUND ART:

Modern power transformers are usually oil-cooled. The core, consisting of a number of core legs joined by yokes, and the windings (primary, secondary, control), are immersed in a closed container filled with oil. Heat generated in coils and core is removed by the oil circulating internally through coils and core, which transfers the heat to the surrounding air via the walls of the container. The oil circulation may either be forced, the oil being pumped around, or it may be natural, produced by temperature differences in the oil. The circulating oil is cooled externally by arrangements for air-cooling or water-cooling. External air-cooling may be either forced or through natural convection. Besides its role as conveyor of heat, the oil also has an insulating function in oil-cooled transformers for high voltage.

Dry transformers are usually air-cooled. They are usually cooled through natural convection since today's dry transformers are used at low power loads. The present technology relates to axial cooling ducts produced by means of a pleated winding as described in GB 1,147,049, axial ducts for cooling windings embedded in casting resin as described in EP 83107410.9, and the use of cross-current fans at peak loads as described in SE 7303919-0.

The cooling requirement is greater for a cable-wound power transformer. Forced convection is necessary to satisfy the cooling requirement in all the windings. Natural convection is not sufficient to cool the cable windings. A short transport route for the heat to the coolant is important and also

that it is efficiently transferred to the coolant. It is therefore important that all windings are in direct contact with sufficient quantities of coolant.

Through DE-A1-2854520, for instance, a resin-embedded coil with highly flexible plaited cable is known, particularly a commutation coil for a rectifier assembly, provided with wound cooling ducts. However, it is not only a question of taking into consideration a transformer/ reactor provided with high-voltage cable with its particular electric/magnetic problems.

According to US 5 036 165 a conductor is known having insulation provided with an inner and an outer layer of semiconducting pyrolized glassfiber. It is also known to provide conductors in a dynamo-electric machine with such insulation, e.g. as described in US 5 066 881 where a semi-conducting pyrolized glassfiber layer is in contact with both the parallel rods forming the conductor and the insulation in the stator slot is surrounded by an outer layer of semiconducting pyrolized glassfiber. The pyrolized glassfiber material is described as suitable since it retains its resistivity even after impregnating treatment.

OBJECT OF THE INVENTION:

The object of the invention is to provide a transformer/reactor with a winding procedure whereby additional members are included in the winding in one or more of the spaces formed between each turn of the winding. The additional members are selected as required and may be cooling tubes for gas or liquid, empty tubes which can be used as desired, earthing arrangements, stabilizing compounds, mechanical stabilizers, noise-suppressing members or transducers of various types.

Another object of the invention is to provide a transformer of the type described in the introduction which will enable gas or preferably water-cooling of a cable-wound power transformer. The invention aims at cooling each turn in the windings, the coolant being correctly distributed to satisfy the various cooling requirements of the windings.

The invention also aims at eliminating the use of oil-cooling in power transformers and thus achieving internal cooling which results in lower weight and higher filling factor, and consequently lower costs.

SUMMARY OF THE INVENTION:

The objects mentioned above are achieved by the method and device according to the invention having the features defined in the appended claims.

The present invention relates to a transformer or a reactor comprising a transformer core wound with cable, arranged so that the winding is provided with a cooling duct between each cable turn. The cooling duct is also arranged to transport water to cool all winding turns in the transformer.

In the device according to the invention the windings are preferably of a type corresponding to cables with solid extruded insulation used nowadays for power distribution, e.g. XLPE cables or cables with EPR insulation. Such a cable comprises an inner conductor composed of one or more strand parts, an inner semiconducting layer surrounding the conductor, a solid insulating layer surrounding the inner semiconducting layer, and an outer semiconducting layer surrounding the insulating layer. Such cables are flexible, which is an essential property in this context since the technology for the device according to the invention is based primarily on a winding system in which the winding is performed with conductors which are bent during assembly. A XLPE cable normally has a flexibility corsponding to a radius of curvature of approximately 20 cm for a cable 30 mm in diameter and a radius of curvature of approximately 65 cm for a cable 80 mm in diameter. In this application the term "flexible" thus refers to a winding flexible down to a radius of curvature in the order of four times the cable diameter, preferably 8-12 times the cable diameter.

The winding should be constructed so that it can retain its properties even when it is bent and when it is subjected to thermal stress during operation. It is extremely important in this context that the layers retain their adhesion to each other. The material properties of the layers, particularly their

elasticity and their relative coefficients of thermal expansion are decisive h re. In a XLPE cable, for instance, the insulating layer is of cross-linked low-density polyethylene and the semiconducting layer is of polyethylene with soot and metal particles mixed in. Fluctuations in volume as a result of temperature fluctuations are absorbed entirely as changes in radius in the cable and, thanks to the comparatively slight difference in the coefficients of thermal expansion in relation to the elasticity of these materials, the radial expansion will be able to occur without the layers loosening from each other.

The material combinations stated above should be considered only as examples. Other combinations fulfilling the conditions specified and also the condition of being semiconducting, i.e. having resistivity within the range of 10^{-1}-10^{6} ohm-cm, e.g. 1-500 ohm-cm, or 10-200 ohm-cm, naturally also fall within the scope of the invention.

The insulating layer may consist, for example, of a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentane (PMP), cross-linked materials such as cross-linked polyethylene (XLPE), or rubber such as ethylene propylene rubber (EPR) or silicon rubber.

The inner and outer semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed in.

The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed in or not - at least in the proportions required to achieve the conductivity necessary according to the invention. The insulating layer and the semiconducting layers thus have substantially the same coefficients of thermal expansion.

Ethylene-vinyl-acetate copolymers/nitrile rubber, butylymp polyethylene, ethylene-butyl-acrylate-copolymers and thylene-ethyl-acrylate copolymers may also constitute suitable polymers for the semiconducting layers.

Even when different types of material are used as base in the various layers, it is desirable for their coefficients of thermal expansion to be substantially the same. This is the case with the combination of the materials listed above.

The materials listed above have relatively good elasticity, with an E-modulus of E<500 MPa, preferably <200 MPa. The elasticity is sufficient for any minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction of the elasticity so that no cracks or other damage appear and so that the layers are not released from each other. The material in the layers is elastic, and the adhesion between the layers is at least of the same magnitude as the weakest of the materials.

The conductivity of the two semiconducting layers is sufficient to substantially equalize the potential along each layer. The conductivity of the outer semiconducting layer is sufficiently large to contain the electrical field in the cable, but sufficiently small not to give rise to significant losses due to currents induced in the longitudinal direction of the layer.

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electrical field between them.

There is, of course, nothing to prevent one or more additional semiconducting layers being arranged in the insulating layer.

The cooling tubes according to the invention consist of electrically insulating material, e.g. cross-linked polyethylene in the form of circular "XLPE tubes" which are alternated with the cables so that the heat is transferred from the cables to the cooling tubes primarily through heat conduction. The use of polymer tube material avoids problems with

induced voltages and eddy-currents in the tubes. Besides which, polymer tub s ar considerably mor flexible than metal tubes. Neither need polymer tubes have circular cross section but may have quadratic or some other cross section which means that they take up the entire space between the four adjacent cables. To enable each cooling tube or hose to be led in and led out in each cable layer, each cable layer is wound separately and is spliced and connected in series afterwards. The space between cables and cooling tubes is also filled with a thermally conducting compound.

The transformer core according to the invention can be cooled with either gas or liquid, e.g. with air from a fan and/or with water circulating in the cooling blocks provided with cooling ducts. Another possible coolant is helium.

The invention also relates to a method of manufacturing a cable-wound transformer/reactor, and a transformer/reactor manufactured in accordance with the method, wherein additional members consisting of transducers of various types, cooling tubes, earthing devices, stabilizing compounds, mechanical stabilizers, noise-suppressing members or empty tubes may be wound into the winding coil when the cable is wound around the legs of the transformer/reactor. The empty tubes may be provided with control or measuring windings, additional magnetic material, extra windings, etc. During winding of these empty tubes they may be provided with pulling wires.

BRIEF DESCRIPTION OF THE DRAWINGS:

The invention will now be described in more detail with reference to the accompanying drawings.

Figure 1 shows, schematically and partly in section, a three-phase power transformer according to the invention.

Figure 2 shows schematically a section through a coil with iron core comprising four embodiments 2a, 2b, 2c, 2d, according to the present invention.

Figure 3 shows schematically a section through a coil with iron core comprising additional embodiments 3a, 3b, 3c, 3d, 3e, 3f, according to the present invention.

DESCRIPTION OF THE INVENTION:

Figure 1 shows a power transformer 1 provided with three winding coils 2, 3, 4, each comprising a low-voltage winding 6 and a high-voltage winding 5. The winding coils 2, 3, 4 are wound around legs 22, 23, 24, respectively, of an iron core where the legs are joined on each side of the coils by an upper and a lower yoke 7, 8 in the iron core. The legs 22, 23, 24 and the yoke 7, 8 thus form the total iron core of the transformer 1.

Figure 2 shows a cross-sectional view of part of a power transformer wound with high-voltage cables 111 for use as transformer winding in accordance with the present invention. The high-voltage cable 111 comprises a number of strands 112 of copper (Cu), for instance, having circular cross section. These strands 112 are arranged in the middle of the high-voltage cable 111. Around the strands 112 is a first semi-conducting layer 113. Around the first semi-conducting layer 113 is an insulating layer 114, e.g. XLPE insulation. Around the insulating layer 114 is a second semi-conducting layer 115. Thus the concept "high-voltage cable" in the present application does not include the outer sheath that normally surrounds such cables for power distribution. The high-voltage cable 111 is wound around a leg 24 which is joined to the other legs in the transformer by a yoke 7.

When the high-voltage cable is wound with the cable straight, as shown in the embodiment according to Figure 2, a space 8 is formed between the cables, this space being defined by the cylindrical sheath surfaces, i.e. the second semi-conducting layer 115, of the four adjacent cables 111. The space 8 is provided with cooling ducts for coolant in liquid phase, suitably water, which ducts may be designed in any of the four ways shown in the Figure.

The first embodiment of the transformer, designated 2a, is provided with cylindrical cooling tubes 9 of cross-linked polyethylene (XLPE tubes), surrounded by a spacing agent 10 acting as a thermally conducting compound, which completely fills out the space 8 between the cooling tube 9 and the cylindrical sheath surfaces of each cable 111.

The second embodiment of the transformer, designated 2b, is provided with quadratic cooling tubes 11, also made of cross-linked polyethylene (XLPE tubes) and surrounded by a spacing agent 10 acting as a thermally conducting compound. The spacing agent 10 completely fills out the space 8 between the cooling tube 11 and each cable 111. The quadratic shape of the cooling tube 11 allows greater utilization of the space 8 for cooling purposes.

The third embodiment of the transformer, designated 2c, is provided with concave quadratic cooling tubes 12, the sides having the same curved shape as the cylindrical cables. This shape further minimizes the remaining space between cooling tube 12 and cable in comparison with the second embodiment. In this embodiment also the cooling tubes 12 are made of cross-linked polyethylene (XLPE tubes), here too surrounded by a spacing agent 10 acting as a thermally conducting compound which completely fills out the space 8 between the cooling tube 12 and each cable 111.

In all three embodiments described above coolant in the form of cooling water flows in respective cooling tubes 9, 11, 12. However, a gaseous coolant such as helium is also possible. Other types of liquid coolants in the tubes are also possible.

The fourth embodiment of the transformer, designated 2d, is provided with cylindrical XLPE tubes 13 running in pairs inside a quadratic insert tube 14 of cross-linked polyethylene (XLPE tubes), the XLPE tubes 13 being surrounded by spacing agent 10 inside the insert tube 14, said insert tube 14 also being surrounded by spacing agent 10 which completely fills the space 8 between the cooling tube 9 and each cable 111. The spacing

agent 10 acts as a thermally conducting compound both inside and outside the insert tube 14.

The thermally conducting compound in the form of spacing agent in all the embodiments described consists of one or two-component curing silicon rubber filled with heat-conducting filler such as aluminium oxide. In uncured state the material is given such rheological properties that it is liquid at high shear rates (pumpable) and is in paste form at rest.

In a first procedure according to the invention the compound is first sprayed onto the cables, after which the cooling tube 9, 11, 12 or the insert tube 14 is placed in the groove formed between winding turns of the cable. Fresh compound is sprayed onto the cooling tube 9, 11, 12 or the insert 14 and another turn of cable is wound, and so on. The winding drum rotates during winding, but it may stand still without the spacing agent 10 running off.

In a second procedure according to the invention a curing silicon rubber compound is cast or extruded as spacing agent around the cooling tube 9, 11, 12 or the insert 14. In cured state the compound has such a consistency (similar to modelling clay) that it is moulded to fill out the remaining space between the cables during winding.

According to Figure 2, furthermore, the iron core is provided with a yoke 7 and a leg 24, the yoke being provided with a longitudinal cooling channel 15.

The cooling requirement is different for the windings and the flow of liquid in the various cooling tubes is thus also different. A higher flow is generally required in the tubes situated close to the low-voltage winding than in the tubes situated close to the high-voltage winding. In order to achieve the correct flow distribution the tubes may have different diameters or be connected in different series and parallel combinations.

Polymer cooling tubes can be manufactured from many materials, such as polyethylene, polypropene, polybutene, polyvinylidene fluoride,

polytetrafluoroethylene or be filled and r inforced elastomers. Among these polyethylene with high density, HDPE, is preferred since its thermal conductivity increases with increased density. If the polyethylene is cross-linked, which can be achieved by peroxide-splitting, silane cross-linking or radiation cross-linking, its ability to withstand pressure at increased temperature is increased and at the same time the risk of stress corrosion disappears.

The tubes must be embedded since the thermal resistance between tube and cables will otherwise be too high. To increase the heat transfer between tube and winding, the space is filled with a cross-linkable casting compound. This may consist of a polymer which has low viscosity and can thus be filled with a high percentage of heat-conducting filler before being injected into the space where it is converted to a non-liquid compound by a chemical reaction. Examples of suitable compounds are acryl, epoxy, unsaturated polyester, polyurethane and silicon, the latter being preferred since it is non-toxic. Heat-conducting filler may also comprise oxides of aluminium, magnesium, iron or zinc, nitrides of boron or aluminium, silicon carbide. A mixture of for instance aluminium oxide and silicon, i.e. polydimethyl siloxane with vinyl groups which react with hydrogen polydimethyl siloxane in the presence of a platinum catalyst, is forced at over-pressure into the space between the XLPE tube and the winding, after which curing is effected by the hydrogen atoms being added to the vinyl groups.

Figure 3 shows a corresponding picture to figure 2, but in which the cooling tubes are combined or replaced by other types of members. The figure indicates which other members are suitable for being wound together with the high-voltage cable 111. The high-voltage cable is of the same shape as those which have been described as embodiments under figure 2. Also the transformer/reactor core is similar to the one shown in figure 2.

Figure 3a shows an additional member in the form of an empty tubular member 50 arranged to be wound in together with the high-voltage cable 111. This tub 50 is also surrounded by a spacer 10 which in this cas

may also act as a thermally conducting compound but which may be given other properties suitable for the additional member. The tube 50 is intended to enable insertion of various components into the winding, such as extra windings for control or measurement. In other embodiments magnetic material may be inserted into the tubes in order to alter the electrical and/or magnetic properties of the transformer/reactor. It is also possible to "stitch" in extra windings of the same type as the high-voltage cable 111 described above. In such a method of inserting a winding, the tube is lubricated with a suitable agent, e.g. soapy water. To facilitate the insertion of various components into the tube 50 it is provided with one or more pulling wires 51.

Another embodiment is illustrated as 3b in the Figure, the additional member being arranged as an earthing member 55. This is elliptical in the Figure but may of course have different cross-sectional shape.

According to yet another embodiment illustrated in Figure 3c, the additional member is in the form of a stabilizing compound 60 which is stiffer than the surrounding spacer 10 and has a defined shape even at room temperature during storage.

Figure 3d shows an embodiment with an additional member in the form of a mechanical stabilizer 65 which may be produced from a number of loose, arc-shaped parts or as a wire which can be rolled in.

Figure 3e shows an embodiment with an additional member in the form of a noise-suppressing member 70 which is star-shaped in order to absorb mechanical vibrations.

Figure 3f shows an embodiment with an additional member in the form of an electric transducer 75 which is wound into the winding. The transducer is also provided with conductors, not shown, for connection to calculation, evaluation and control equipment.

The spacer 10 completely fills the space 8 between each additional memb r and the surrounding high-voltage cables 111 in all the embodiments described above.

The invention is not limited to the examples shown. Several modifications are feasible within the scope of the invention. The cables need not be symmetrically placed as shown in Figures 2-3, in which case the space between adjacent windings will have a different appearance and the additional members must then be adapted to the shape of the space.

CLAIMS

1. Method of manufacturing a gas or water-cooled transformer/reactor having at least one winding, characterized in that the winding comprises a high-voltage cable (111) having an insulated electric conductor comprising at least one live conductor (112), also comprising a first layer (113) with semiconducting properties arranged surrounding the live conductor (112), a solid insulating layer (114) arranged surrounding said first layer (113), and a second layer (115) with semiconducting properties arranged surrounding the insulating layer (114), and in that the transformer/reactor is designed with at least one additional member (9, 11, 12, 13, 14, 50, 55, 60, 65, 70, 75) which is wound into the winding (2, 3, 4) when the high-voltage cable (111) is wound around the legs (22, 23, 24) of the transformer/reactor.

2. Method as claimed in claim 1, characterized in that
   a) a first layer of cable is wound,
   b) additional members (9, 11, 12, 13, 14, 50, 55, 60, 65, 70, 75) are wound on or applied,
   c) an additional layer of cable is wound, whereupon steps b) and c) are repeated until the entire coil is fully wound.

3. Method as claimed in claim 1, characterized in that the high-voltage cable is wound at the same time as the additional members (9, 11, 12, 13, 14, 50, 55, 60, 65, 70, 75) are being wound on or applied.

4. Method as claimed in any of claims 2-3, characterized in that spacers (10) are placed on the winding before the additional members (9, 11, 12, 13, 14, 50, 55, 60, 65, 70, 75) are wound on or applied.

5. Method as claimed in claim 4, characterized in that spacers (10) are also placed on the winding after the additional members (9, 11, 12, 13, 14, 50, 55, 60, 65, 70, 75) have been wound on or applied.

6. Method as claimed in any of claims 1-5, characteriz d in that a cooling tube (9, 11, 12, 13) is wound as additional member in the winding.

7. Method as claimed in any of claims 1-5, characterized in that a single tubular member (50), an earthing member (55), a stabilizing compound (60), a mechanical stabilizer (65), a noise-suppressing member (70) or an electric transducer (75) is wound in as additional member in the winding.

8. Method as claimed in claim 6, characterized in that water flows through the cooling tube (9, 11, 12, 13).

9. Method as claimed in claim 8, characterized in that

a) a thermally conducting compound (10) is sprayed between the spaces formed between the turns of the winding after the first layer of cable has been wound,

b) additional thermally conducting compound (10) is sprayed onto the cooling tube (9, 11, 12) or insulating tube (14) after the cooling tube (9, 11, 12) or insulating tube (14) has been wound in the spaces formed between the winding turns.

10. Method as claimed in claim 8, characterized in that

a) a cooling tube (9, 11, 12) or an insulating tube (14) which has been extruded or embedded in a thermally conducting compound (10) is wound onto the cable after the first layer of cable has been wound,

b) the thermally conducting compound (10) is shaped to abut the cables when the second layer of cable is wound another turn.

11. Gas or water-cooled transformer/reactor (1) having at least one winding wound around the legs (22, 23, 24) of the transformer/reactor, characterized in that the winding (2, 3, 4) is performed using an insulated electric conductor comprising at least one live conductor (112), also comprising a first layer (113) with semiconducting properties

arranged surrounding the live conductor, a solid insulating lay r (114) arranged surrounding said first layer (113), and a second layer (115) with semiconducting properties arranged surrounding the insulating layer (114), and in that the device comprises at least one additional member (9, 11, 12, 13, 14, 50, 55, 60, 65, 70, 75) wound into the winding (2, 3, 4).

12. Transformer/reactor as claimed in claim 11, characterized in that the high-voltage cable (111) is cylindrical in shape.

13. Transformer/reactor as claimed in any of claims 11-12, characterized in that at least one additional member (9, 11, 12, 13, 14, 50, 55, 60, 65, 70, 75) is placed in the space (8) formed between each cable (111) during the winding procedure.

14. Transformer/reactor as claimed in any of claims 11-12, characterized in that the additional member consists of at least one cooling tube (9, 11, 12, 14) placed in a space (8) formed between each cable (111) during the winding procedure, the space (8) that remains between the cooling tubes (9, 11, 12, 14) and the cables being filled with a thermally conducting compound (10).

15. Transformer/reactor as claimed in claim 14, characterized in that a cooling tube (9) with circular cross section is placed in the space (8).

16. Transformer/reactor as claimed in claim 14, characterized in that a cooling tube (11) with quadratic cross section is placed in the space (8).

17. Transformer/reactor as claimed in claim 14, characterized in that a quadratic cooling tube (12) with concave sides is placed in the space (8).

18. Transformer/reactor as claimed in claim 14, characterized in that the cooling tube (13) is surrounded by an insert tube containing filler (10).

19. Transformer/reactor as claimed in any of claims 11-12, characterized in that the additional member consists of a single tubular member (50), an earthing member (55), a stabilizing compound (60), a mechanical stabilizer (65), a noise-suppressing member (70) or an electric transducer (75) in a space (8) between each cable (111), the space (8) that remains between the additional member (50, 55, 60, 65, 70, 75) and the cables being filled with a thermally conducting compound (10).

20. Transformer/reactor as claimed in any of claims 14-19, characterized in that the thermally conducting compound (10) has low viscosity at high shear rate and is in paste form at rest.

21. Transformer/reactor as claimed in claim 20, characterized in that the thermally conducting compound (10) consists of a one or two-component curing silicon rubber provided with a heat-conducting filler.

22. Transformer/reactor as claimed in any of claims 14-21, characterized in that the filler consists of either aluminium oxide, boron nitride or silicon carbide.

23. Transformer/reactor as claimed in any of claims 14-18 or 20-22, characterized in that the cooling tube (13) is made of dielectric material such as polyethylene, polypropene, polybutene, polyvinylidene fluoride, polytetrafluoroethylene or filled and reinforced elastomers.

24. Transformer/reactor as claimed in any of claims 14-18 or 20-23, characterized in that the cooling tube (13) is manufactured from high-density polyethylene (HDPE).

25. Transformer/reactor as claimed in any of claims 14-18 or 20-24, characterized in that the cooling tube (13) is manufactured from cross-linked polyethylene (XLPE).

26. Transformer/reactor as claimed in any of claims 11-25, characterized in that the high-voltage cable (111) is of a type comprising a conductor with a plurality of strand parts (112), a semiconducting layer (113) surrounding the conductor, an insulating layer (114) surrounding the inner semiconducting layer, and an outer semiconducting layer (115) surrounding the insulating layer.

27. Transformer/reactor as claimed in claim 26, characterized in that the high-voltage cable (111) has a diameter in the range of 20-250 mm and a conducting area in the range of 40-3000 mm^2.

28. Transformer/reactor as claimed in any of claims 11-27, characterized in that the insulated conductor or high-voltage cable (111) is flexible.

29. Transformer/reactor as claimed in claim 28, characterized in that the layers (113, 114, 115) are arranged to adhere to each other even when the insulated conductor or high-voltage cable (111) is bent.

30. Transformer/reactor as claimed in any of claims 11-29, characterized in that at least two adjacent layers (113, 114, 115) of the winding have coefficients of thermal expansion of substantially the same magnitude.

31. Transformer/reactor as claimed in any of claims 14-30, characterized in that all coolant, in the form of gas or liquid, designed to cooling the transformer/reactor is arranged to flow through the cooling tube (13).

32. Transformer/reactor as claimed in any of claims 11-31, characterized in that the winding is flexible and comprises an electrically conducting core surrounded by an inner semiconducting layer, an insulating layer of solid material surrounding the inner semiconducting layer, and an outer semiconducting layer surrounding the insulating layer, which layers adhere to each other.

33. Transformer/reactor as claimed in any of claims 11-32, characterized in that said layers are of materials having such elasticity and such relation between their coefficients of thermal expansion that the fluctuations in volume in the layers caused by temperature fluctuations during operation can be absorbed by the elasticity of the materials so that the layers retain their adhesion to each other at the temperature fluctuations occurring during operation.

34. Transformer/reactor as claimed in any of claims 11-33, characterized in that the materials in said layers have high elasticity, preferably with an E-modulus of less than 500 MPa, more preferably less than 200 MPa.

35. Transformer/reactor as claimed in any of claims 11-34, characterized in that the coefficients of thermal expansion of the materials in said layers are of substantially the same magnitude.

36. Transformer/reactor as claimed in any of claims 11-35, characterized in that the adhesion between the layers is of at least the same order of magnitude as in the weakest of the materials.

37. Transformer/reactor as claimed in any of claims 11-36, characterized in that each semiconducting layer essentially constitutes an equipotential surface.

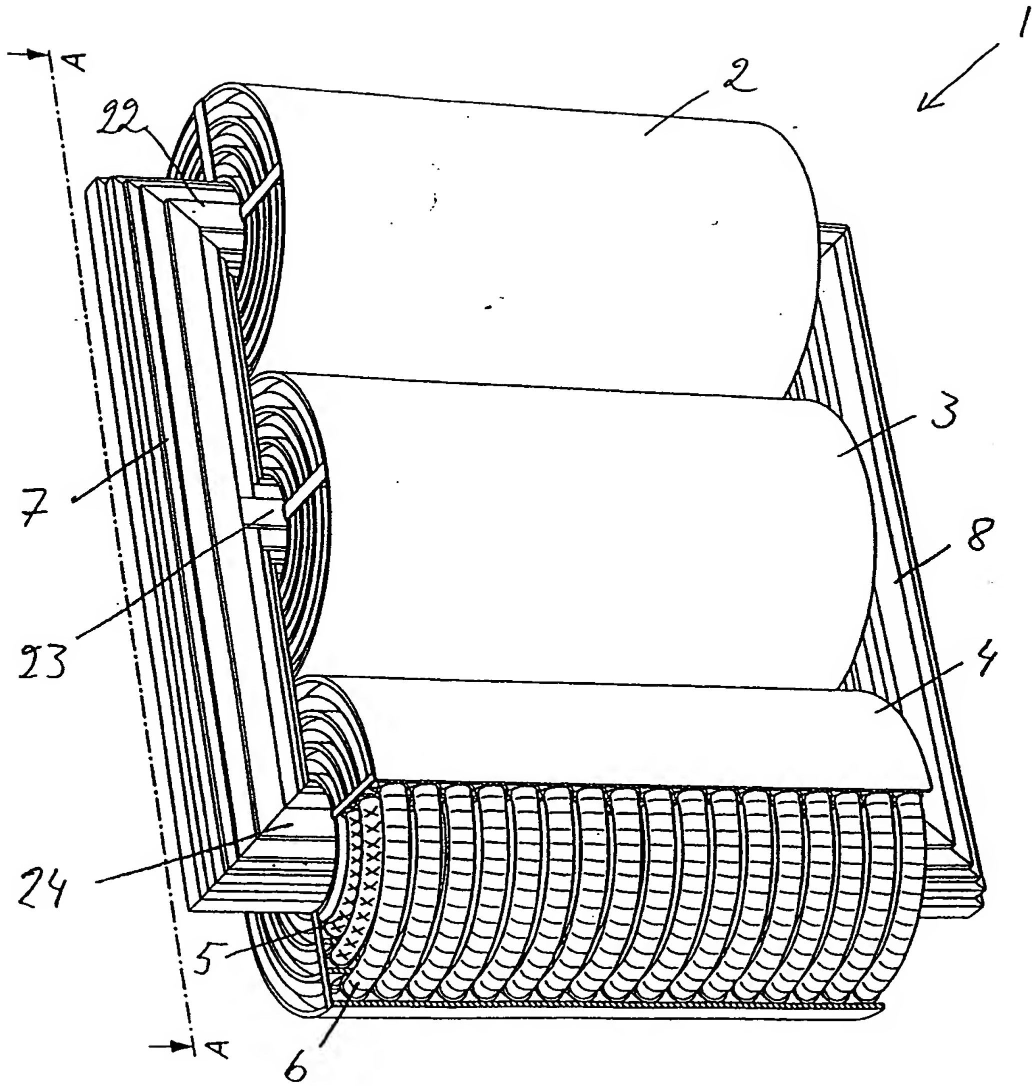

Fig 1

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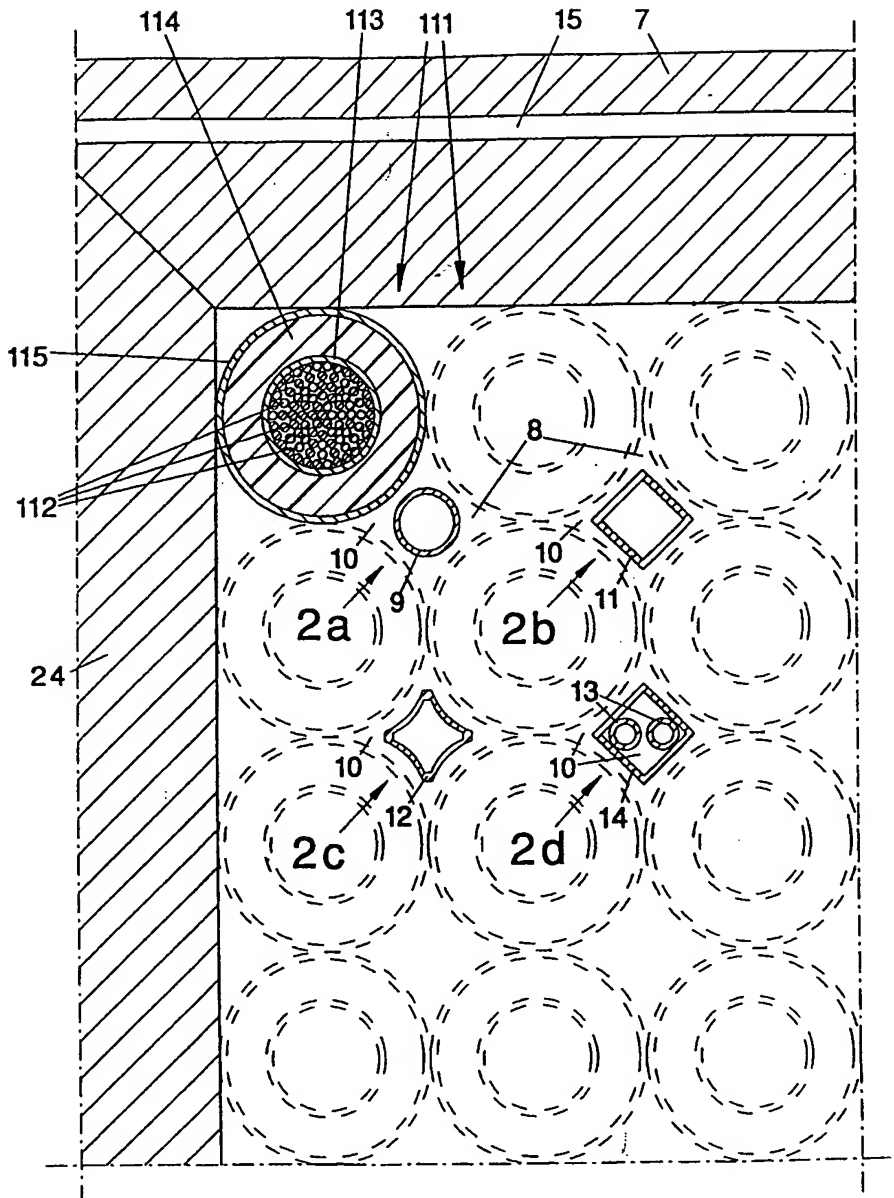

Fig 2

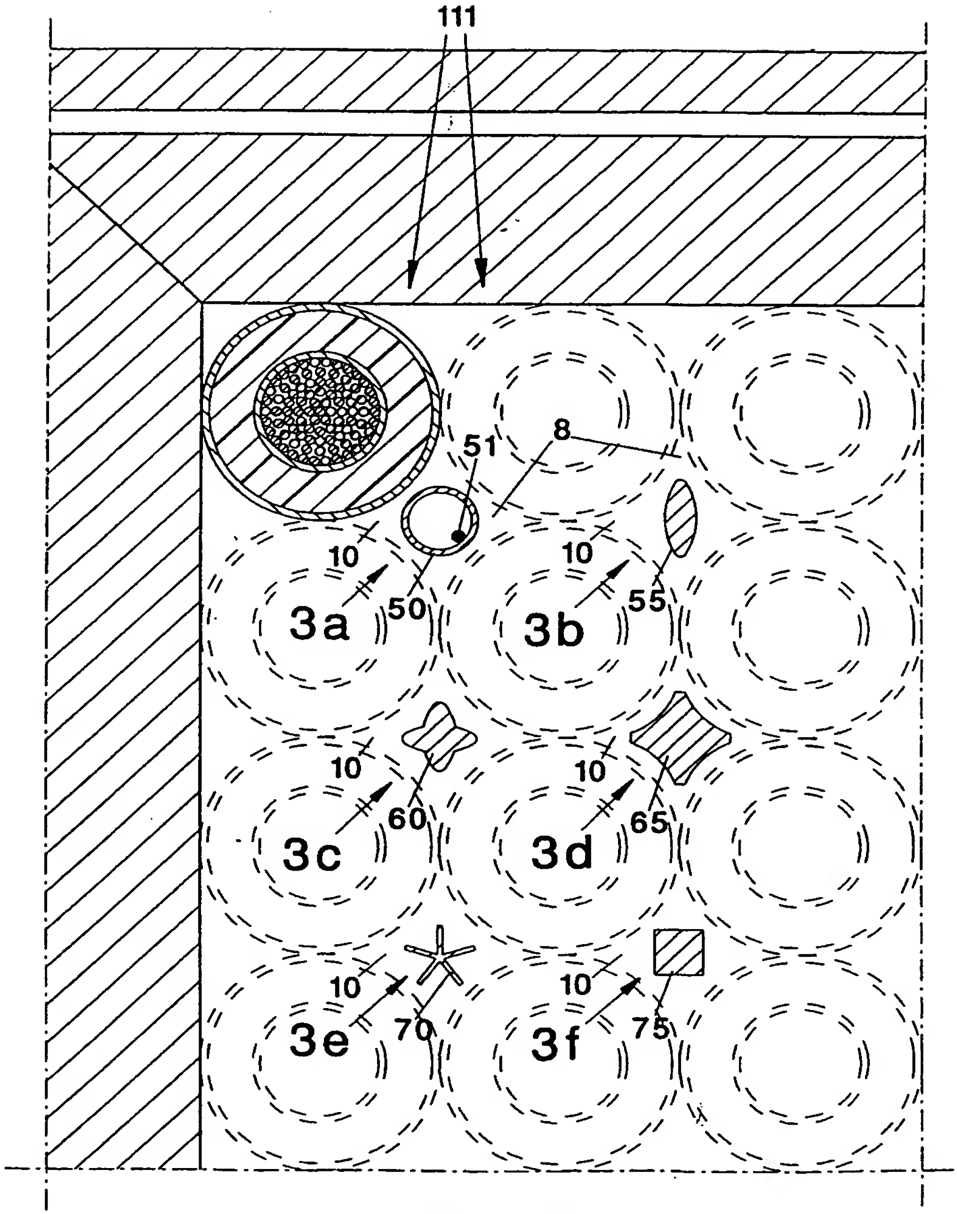

Fig 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00177

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01F 27/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EDOC, WPIL, JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 2854520 A1 (BROWN, BOVERI & CIE AG), 26 June 1980 (26.06.80), see whole document --	1
A	US 5036165 A (RICHARD K. ELTON ET AL), 30 July 1991 (30.07.91), abstract -- --------	1

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 June 1998	17 -06- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Magnus Westöö Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

29/04/98

International application No.
PCT/SE 98/00177

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		SE 436950 B,C	28/01/85
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US 5036165 A	30/07/91	US 5066881 A	19/11/91
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